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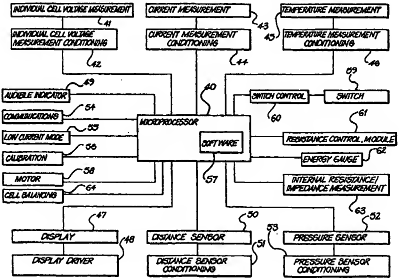
With international search report.

(54) Title: ENERGY GAUGE



(57) Abstract

An energy gauge for indicating the amount of residual power available from a battery includes means for storing a predetermined value of a power parameter indicative of full battery capacity, means for determining the instantaneous power consumption indicated by the parameter, means for integrating the power consumption indicative of the parameter since commencement of use of the battery, means for subtracting the integrated consumption from the stored value of full capacity to provide a value of power remaining, and readout means for providing a representation of the power remaining.

ENERGY GAUGE

FIELD OF THE INVENTION

This invention relates to an energy gauge for indicating the amount of residual power available from a battery.

BACKGROUND ART

The battery industry has seen increased demand for battery management technology, primarily due to the consumers' ever-increasing requirements for the convenience of battery-powered portable equipment such as cellular phones and laptop computers. Additionally, the battery industry is seeing a movement toward an increased emphasis on electric motor-driven tools and zero emission vehicles with the primary power source for these new generation vehicles being batteries. This movement is due to rapidly increasing government regulations and consumer concerns about air and noise pollution. Another area which requires high efficiency batteries is energy storage applications such as load-levelling, emergency/standby power and power quality systems for sensitive electronic components.

As a result of the increasing demand of battery-powered equipment, the battery industry is under competitive pressure to produce an ideal cell. An ideal cell is a cell that weighs almost nothing, takes up no space, provides excellent cycle life and has ideal charge/discharge performance and does not itself produce an environmental hazard at the end of its life. The most popular technology utilised by the battery industry is the lead-acid battery, which is being challenged to meet higher energy density, smaller size, better performance levels, longer cycle life and guaranteed recyclability.

Several manufacturers are researching exotic batteries, including

nickel-metal-hydride, lithium-ion and the like but generally these types of batteries are too expensive to make their use economically viable at this stage, particularly for one of the fastest growing markets on earth, two/three wheeled passenger vehicles. It is well recognised that battery performance, even that of the existing lead-acid battery, can be improved through proper management of the operating conditions of the battery.

There is a need for an accurate measuring device with appropriate intelligence to monitor and determine the amount of power remaining in a battery and providing instant information to an operator.

SUMMARY OF THE INVENTION

According to the invention there is provided an energy gauge for indicating the amount of residual power available from a battery comprising:-

(i) means for storing a predetermined value of a power parameter indicative of full battery capacity,

(ii) means for determining the instantaneous power consumption indicated by the parameter,

(iii) means for integrating the power consumption indicative of the paramater since commencement of use of the battery,

(iv) means for subtracting the integrated consumption from the stored value of full capacity to provide a value of power remaining, and

(v) readout means for providing a representation of the power remaining.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a battery management system for providing a predetermined power output from a battery system,

Fig. 2 is a block diagram of a generalised battery management system according to a second embodiment,

Fig. 3 is a block diagram of the power control system shown in Fig. 1 applied to a lead-acid battery system,

Fig. 4 is a graph of cycle numbers against battery capacity for a lead acid battery with and without the power control system of Fig. 2, and

Fig. 5 is a block diagram of the power control device shown in Fig. 1. applied to a Redox-Gel battery system.

MODES OF PERFORMING THE INVENTION

The battery management system 10 shown in Fig. 1 is adapted to provide a predetermined power output from a battery system 11 at the terminals or output means 12 to which a load such as an electrical vehicle is connected. Between the output terminals 12 and the terminals 13 of the battery system 11 there is a control means 14 which senses predetermined operating parameters of the battery system 11. The control means 14 supplies power from the battery system 11 to the output terminals 12 during a first mode of operation.

First capacitor means 15 connected between the battery system 11 and the control means 14 stores a predetermined quantity of power from the battery system 11 during the first mode of operation of the control means 14 and supplies its stored power to the battery system 11 in response to a command signal from the control means 14 when the control means is in a second mode of operation.

Second capacitor means 16 which is connected between the output terminals 12 and the control means 14 stores a predetermined amount of power from the battery system 11 when the control means 14 is in its first

mode of operation and supplies its stored power to the output terminals 12 in response to a command signal from the control means 14 when the control means 14 is in its second mode of operation.

Thus, the power control system incorporates two capacitor networks and when the control means senses, for example, that the polarisation level in the battery system 11 is too high or that a pre-set time interval has elapsed since power was first supplied to the load, it initiates a back charge to the battery system 11. In this discharge cycle, the control means 14 allows the energy stored in the first capacitor network 15 to charge the battery system 11 and at the same time the second capacitor means 16 supplies uninterrupted power to the output terminals 12. The time interval for this reverse cycle or discharge cycle is very small and as it is very efficient it can be performed at regular intervals.

The reverse charge has the ability to disrupt and minimise the effects and associated losses of polarisation within the battery system.

The power control system may also work in conjunction with a charger to provide optimum performance and battery care at all times during its operation. The power control system may be adapted to prevent an unauthorised type of charger being connected to the battery system thereby preventing a potential abuse and ensuring that the vehicle owner does not attempt to charge the battery system with an incorrect charger at home.

The power control system, the charger and the vehicle may incorporate individual electronic signatures so that the entire system can be tracked and monitored with a high degree of accuracy. Each time a battery system is installed into a charger unit, the power control system will

identify itself, the vehicle from which it has been removed as well as the user.

The charger unit may monitor the energy level of the battery and credit the users for this value, add the cost of the exchange, the electricity and a monthly rental for the battery. Upon receipt of this payment either by cash or credit card, a new battery is released and installed into the vehicle. If the client has abused or tampered with the battery anyway this will be identified by the charger.

The control system can be adapted to not only identify the energy level of the battery, but it can also assess the driving range left based on current energy usage levels. Thus, the vehicle driver will know how many kilometres can be travelled on the remaining level of energy.

Each charger unit may be linked via a telemetry system to an operation centre which enables constant monitoring of all stations in the network of charging stations.

The power control system may include the functions and features of speed control modules which means that the vehicle manager can eliminate a speed control device from the vehicle and simply control the output via the power control system. This reduces vehicle costs, reduces manufacturer warranty exposure and can provide continuous performance monitoring via the telemetry communication system.

The power control system may be applied to various battery systems such as valve-regulated lead acid batteries, nickel metal hydride batteries and redox-gel batteries with each system having its benefits and specific target applications.

The power control system may also be used to improve the standby performance of remote area power system, load levelling and emergency

back-up battery systems. Stationary battery systems used in remote area power systems and emergency back-up applications may be left fully charged for extended periods. As cells self-discharge at different rates the power control system can be programmed to scan the individual cell conditions periodically and use cell-balancing techniques to balance the cells internally. Alternatively, the charging system may be left on standby and be controlled by the power control system as required.

A preferred embodiment of the power control system which is shown in Fig. 2 in block form includes a microprocessor 40 and associated software 57 that manages all of the following described functions. In this instance the microprocessor is 8 bit running at 8MHz, however 4,16, 32 or 64 bit processors can be used. The processor speed could be 4MHz to 166MHz. Alternatively a Digital Signal Processing Chip could be used depending on the individual battery requirements. The microprocessor has EEPROM, ROM and RAM Memory. Alternatively an ASIC (Application Specific Integrated Circuit) could be used.

The individual cell voltage measurement module 41 utilises a separate wire connected to the junction of each cell. This wire is used solely for the measurement of voltage. The voltage of each cell is measured with reference to ground for batteries up to 24 Volts. This can also be accomplished using direct measurement of each cell voltage as the needs and accuracy requirements dictate.

Individual cell voltage measurement conditioning is achieved by module 42 which includes a circuit in which the cell voltages are divided by a resistor network and smoothed by a filter capacitor connected across the ground resistor in the divider. Active filtering using operational amplifiers or other filtering means could be used. The voltages are scaled by the divider

and filter to a voltage suitable for analog to digital conversion. In this case 4.95 Volts represents the expected maximum voltage of each connection to the battery. A 12 bit analog to digital converter is used for each cell voltage to be measured. The analog to digital converter is controlled serially by the microprocessor which converts each measured voltage to the cell voltage by scaling each voltage and subtracting the voltage of the negative side of each cell from the voltage of the positive side of the cell. This is done for each cell and this method is applicable for cell voltages up to 24 or 30 Volts.

Above 24 or 30 Volts multiple stages of the above method can be used by transmitting the serial digital data by means of optically coupled serial communications thus isolating the cell voltages. Also applicable would be the use of a Voltage to Frequency Converter connected across each cell to directly measure the cell voltage and send this information as a frequency to the microprocessor. These Voltage to Frequency converters can be galvanically or optically coupled to the microprocessor which measures the frequency and converts this to a voltage.

The current measurement module 43 measures the voltage across a shunt resistor and scaling this value using a current sense amplifier with active filtering. An alternative to this would be to use a Hall effect device to measure the current with the appropriate signal conditioning.

Current measurement conditioning is achieved by circuit module 44 in which the voltage measured across the shunt is converted to a 0-5Volt signal irrespective of the direction of the current which is then fed to an input of the same 12 bit analog to digital converter used for the measurement of voltage described above. The conditioning circuitry also provides a digital input to the microprocessor indicating the direction of

current flow. This is achieved via an integrated circuit with minimal external components. Discrete component solutions would also be cost effective in this area.

Temperature is measured by circuit module 45 using an integrated circuit temperature sensor mounted on the circuit board. Any number of these can be used and located in different areas for example the battery, individual cells or outside for ambient temperature.

Temperature Measurement conditioning is achieved by circuit module 46 in which the temperature value is a voltage output and a low offset voltage operational amplifier is used to scale this value to a 0-5Volt value suitable for connection to an input of the same analog to digital converter used for voltage and current measurement.

A Liquid Crystal Display 47 is used to display information such as capacity remaining, kilometers remaining and any other information.

The display driver 48 is driven directly by the microprocessor 40 by writing the appropriate value to a memory location based on a lookup table stored inside the microprocessor 40. Depending on the microprocessor requirements and LCD complexity a separate integrated circuit driver may be used. A LED or gas plasma display could also be used. A Liquid Crystal display module may also be used.

Audible indicator module 49 includes a piezo electric buzzer which provides audible signal to the user. This is ideally driven directly from the microprocessor or with a transistor driver if necessary.

A distance sensor 50 is mounted on the wheel should the battery be used in a moving vehicle. This sensor 50 can take the form of either a magnetic pickup where the magnet is located on the wheel and a hall effect

pickup device is mounted on a stationary part of the vehicle or an optical sensor.

Distance sensor conditioning is achieved by a circuit module 51 in which the output of the distance sensor 50 is a frequency that is scaled and measured by the microprocessor 40 which in turn converts this to a speed or distance value.

Pressure sensor module 52 includes a pressure transducer with a low voltage (in the order of 0-100mV) output is located in the battery.

Pressure sensor conditioning module 53 scales the output to 0-5Volts via a precision operational amplifier and fed to the analog to digital converter.

The communications module 54 ensures that all control and communications signals from the battery charger are communicated via a serial bus direct from the microprocessor 40. This serial bus can also access a PC for calibration purposes.

To ensure long battery life all components of the optimiser are chosen for low current consumption. The microprocessor, analog to digital converter, and all other circuitry can be placed in a low current consumption mode by a signal from the microprocessor to the low current mode module 55.

To achieve the required levels of accuracy the analog inputs to the microprocessor are calibrated by the calibration module 56 and the calibration factors and offsets are store in EEPROM memory.

The software 57 is preferably polling orientated as well as being interrupt driven for time critical events such as current time, distance and wheel sensor monitoring for energy use integration.

The software samples current at regular time intervals and integrates current with respect to time to provide amperehours used and remaining data. The amperehours used and remaining is corrected depending on loads during the current cycle. The software is adapted to:-

(i) calculate power and Ampere-Hours consumption,

(ii) calculate average power and average Ampere-Hours consumption,

(iii) calculate power and Ampere-Hour capacity available,

(iv) calculate time available at current Ampere-Hour consumption,

(v) calculate distance available at current Ampere-Hour consumption,

(vi) calculate time available and distance to go at a specified Ampere-our consumption,

(vii) initiates low battery power and/or Ampere-Hour alarm when available capacity approaches critical level, and

(viii) display status of all the above features.

The microprocessor 40 can also drive FETS or IGBT's to control the current to a motor 58. This can provide a single pulse width modulated control for a brushed type motor, or a quasi sinusoid control with multiple outputs for brushless multiple type motors such as reluctance motors or brushless DC motors.

A FET or IGBT switch 59 is used for security and protection of the battery. FETS with a low on resistance are used.

The switch 59 is controlled by switch control module 60 which is driven by the microprocessor 40 and the drive of the FETS or IGBT's

utilises a switched power supply to boost the voltage to enable high side driving.

In the resistance control module 61, the microprocessor controls a FET the function of which is to periodically charge a capacitor to a voltage above the battery voltage and discharge this capacitor into the battery whilst at the same time switch another capacitor whose charge can hold the load current.

The output of an energy gauge 62 is displayed on the LCD display as capacity remaining. This value is calculated by integrating the current over time. Current is sampled at regular intervals and this value is subtracted from an accumulator and then scaled to 100% to give a capacity remaining output.

The internal resistance/impedance module 63 calculated the internal resistance and impedance by means of measuring the change in voltage before and after a step change in current. This can occur both during charge and discharge. AC current or voltage may be injected into the battery and the resultant voltage or current is measured to calculate internal resistance and impedance.

The cell balancing module 64 operates so that when one cell is considered to be self discharged more than others in the group, power is taken from the entire group, converted to an appropriate voltage using a switched mode power converter and distributed to the weakest cell thus balancing the cells.

Conventional lead-acid batteries suffer from limited capacity utilisation, low depth of discharge, short cycle life, low energy density, thermal management problems and the need for constant boost charging to maintain cell equalisation. The lead-acid batteries also require long charge

times and high charge currents can only be used for a few minutes at very low states-of-charge. If high currents are used they normally result in higher than allowable voltages being reached leading to electrolyte loss and a reduction in the battery's capacity. The time to recharge a lead-acid battery with boost charging can be up to 4 hours at best if a proper charge profile is followed.

The cycle life of a lead-acid battery varies greatly depending on the depth-of-discharge reached during cycling. For electric vehicle applications a 90-100% DOD (Depth of Discharge) may not by uncommon and at these DOD levels, the cycle life of conventional deep cycle lead-acid batteries would be approximately 300 cycles.

Fig. 3 shows the power control system 20 applied to a lead-acid battery of proven lead-acid format, however, it utilises advanced spiral wound technology for its cell structures. The twelve individual cells 21 are formed from electrodes with surface large areas, which are spiral would to form individual cells with very low resistance. Advanced electrolytes have been developed to assist in allowing very high currents to be extracted from the battery system. The battery system involves the integration of the power control system 20 with the spiral wound cell technology and improved electrolytes. The cells 21 are connected in series by the bus 22 which is also connected to the first capacitor means 23, the control means 24, second capacitor means 25 and output terminals 26. The dotted line 27 represents the command signal from the control means 24 to the first capacitor means 23. The use of a Valve-Regulated lead-acid format offers, a proven technology at a relatively low cost as a starting point for a "rental energy" system.

By utilising the power control system 20 and reconfiguring the battery design to optimise the benefits of these features, there is provided a battery that offers significant improvements in the form of increased current flow, capacity, increased cycle life and reduced recharge times at only a marginally higher manufactured cost.

This is demonstrated in Fig. 4 which is a graph of cycle numbers against battery capacity for a lead acid battery with and without the power control system of the invention. A cycle is from charging to discharging and back to charging.

The increased current flow capability means that power and capacity utilisation is improved resulting in a higher obtainable amp-hour rating and the extension of vehicle range. The increased cycle life means that the battery can be recharged more times before replaced, thereby, lowering the annual operating costs. The reduced charging times mean that the battery can be turned around faster, thereby, reducing the number of spare batteries required in the rental energy system.

The power control system may also be applied to conventional NiMH batteries which employ advanced processed and high purity materials that normally lead to a very high cost for the battery systems. Expanded nickel foams with high purity nickel hydroxide compounds and processed metal alloy materials all need a very high degree of quality control in order to obtain a high performance battery.

NiMH hydride batteries can also suffer from self-discharge problems and can also be affected by temperature. On certain systems the extraction of high current can cause damage the battery cells and care must be taken not to over charge the batteries. In this respect, advanced battery chargers are needed to ensure proper charging.

The NiMH battery system of this embodiment utilises advanced NiMH technology that has been designed to take full advantage of the benefits provided by the battery power control system. The cell structure utilises spiral would cell technology allowing the production of cells which have a much higher power output capability. The power control system is integrated into the battery pack cells. The power control system has the ability to significantly reduce polarisation effects allowing the battery system to provide higher current without jeopardising cycle life.

The integrated unit is effectively a stand-alone intelligent energy storage system as the power control system monitors all the unit's functions. The power control system can take active steps to maintain optimal battery performance, at the same time resulting in improved cycle life.

This Ni-MH system is ideally suited for a "rental Energy" system as its benefits include high energy density, high power, long cycle life and quick recharge time. The system will allow greater travelling distances for electric vehicles in comparison to the valve regulated battery system but at a slightly higher cost. The production cost, however, of the system of this embodiment is significantly lower than existing products with estimates at current costs indicating a total price for the NiMH system almost 1/10 the price of current available small production units.

The NiMH system is particularly suitable for electric bicycles where a small battery systems offering long range travel is desirable.

The power control system may also be applied to Redox batteries which have been under investigation for many years. These batteries have mainly been in the form of Redox flow batteries which store energy in liquid electrolytes which are stored separately to the battery stack. During

operation, the electrolytes are recirculated through the system and energy is transferred to and from the electrolytes. The redox flow batteries usually suffer from a low energy density and pumping losses associated with recirculating the electrolyte through the system. In certain cases, high self-discharge rates are possible depending on the membranes or if internal shunt currents exist.

The redox gel battery differs from the redox flow principle in that the electrolytes do not need to be re-circulated since the electrolytes are super concentrated gels.

Conventional battery systems employ some form of solid metal electrodes that involve phase transfer reactions. This usually leads to increased weight and loss in efficiencies. The redox gel battery employs super concentrated gels, which contain a high concentration of positive and negative reactive ions in the respective gels. All reactive species are contained in the gels and no phase transfer reactions are involved which leads to high efficiencies due to minimal losses.

The power control system of the invention can be integrated in the Redox gel battery pack to reduce the effects of polarisation. As the gels are super concentrated, polarisation tends to be higher when high loads are applied to the battery system. A power control system specifically designed for the redox gel battery can alleviate many of the constraints in the design of the redox gel cell system.

The power control system 30 shown in Fig. 5 includes a bus system 31 which inter connects the cells 32, the control means 33, the first capacitor means 34, the second capacitor means 35 and the output terminals 36. Line 37 represents the command signal.

The control means 33 specifically designed for the redox gel cell also performs a number of monitoring functions, such as monitoring the individual cell voltages and temperatures. It can also monitor the internal pressure of the sealed battery pack and ascertain the allowable load limits of the system at any given condition. The control means 33 has the added and important ability to be able to take active steps in maintaining optimal battery performance at any state-of-charge. With this high degree of system control the system can utilise its total capacity repeatedly and over a very long cycle life.

This system is extremely cost competitive and offers superior performance to current available energy storage system. The electrodes employed the redox gel cells simply function to allow the transfer of energy into and out of the gel electrolytes. The electrodes are inert and can be produced from specially developed conducting plastic ,materials.

This system incorporates the redox gel cells and the power control system to produce an energy storage system that has almost double the energy density of the NiMH system. The system also has very long cycle life due to the stability of the gel electrolytes. The system has a whole is very cost effective. With its lightweight and robustness it is well suited to the battery exchange process for the "rental energy" vehicles.

Another embodiment of the invention relates to a battery charging and conditioning module that integrates with a battery performable power control system, which is integrated into a battery system.

Battery systems suffer a number of problems with one of the main limitations being incorrect charging or gang charging where the overall battery condition is recorded and an applicable charge applied. This concept however does not allow for the condition of individual cells and

therefore the highest charged cell us usually overcharged and the lowest charged cell is usually undercharged. The result is that the overall battery life is significantly reduced.

Another problem is that batteries cannot accept high charge currents because of the internal effects if internal resistance on the various components. Fast charging usually has the effect of gassing where hydrogen gas is given off which are not only dangerous but also limits the life of the battery due to electrolyte degradation. This charger works in conjunction with the power control system and limits the internal resistance thereby permitting faster recharge rates without affecting the battery cycle life.

The present invention provides a unique battery charging and conditioning module that integrates with a power control system which is integrated into a battery system. The main function of this power control system is to reduce the polarisation effects due to the internal resistance of the batteries. Importantly, it has allowed control of multiple on-board functions such as monitoring individual cells, providing power output control functions, operating in conjunction with special battery charges providing protection and a conditioning function.

Special battery chargers can identify the power control system and therefore the battery module serial number, which are relayed to the operations centre via a telemetry communications systems. Once the battery has been recorded and the clients account verified, the battery charger is permitted, by the power control system, to commence charging.

The actual charging function is carried out in conjunction with the power control system to ensure that each cell is monitored and treated or conditioned to its specific requirements. This capability prevents damage

to cells through undercharging or overcharging and therefore significantly improves the overall battery cycle life.

The battery charger is capable of identifying the type of battery and automatically selects the correct charging format. If an unauthorised battery is installed into the charger it will not permit connection. The charger is also capable, through feedback from the power control system of detecting whether the battery has been charged by any other means or whether the optimisation module or battery have been tampered with in any way and pass this information on to the operations centre.

Each charger unit is linked via a telemetry system to the operations centre, which enables constant monitoring of all stations in the network, plus the location of each battery and status of each account.

INDUSTRIAL APPLICABILITY

The battery management system can be used in a Rental Energy Concept where it is installed into a range of service applications in the form of vending machines, manually installed recharge modules, automatic battery removal and replacement carousels, robotic battery replacement facilities and parking/charging stations.

CLAIMS

1. An energy gauge for indicating the amount of residual power available from a battery comprising:-

(i) means for storing a predetermined value of a power parameter indicative of full battery capacity,

(ii) means for determining the instantaneous power consumption indicated by the parameter,

(iii) means for integrating the power consumption indicative of the paramater since commencement of use of the battery,

(iv) means for subtracting the integrated consumption from the stored value of full capacity to provide a value of power remaining, and

(v) readout means for providing a representation of the power remaining.

2. An energy gauge according to claim 1 where the power parameter is amperehours.

3. An energy gauge according to claim 2 wherein the current is sampled at regular predetermined intervals.

4. An energy gauge according to claim 1 wherein the readout means displays power remaining as a percentage of full capacity.

5. An energy gauge according to claim 1 and further including alarm means for providing an audible alarm when power remaining is less than a predetermined percentage of full battery capacity.

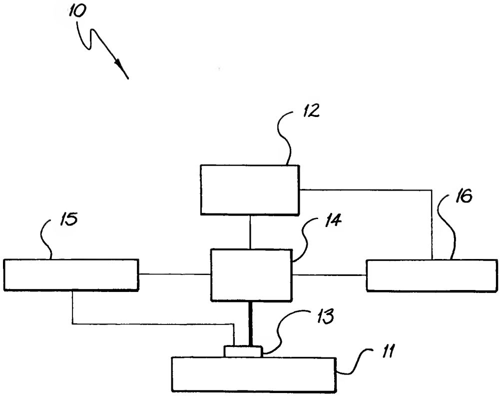


FIG. 1

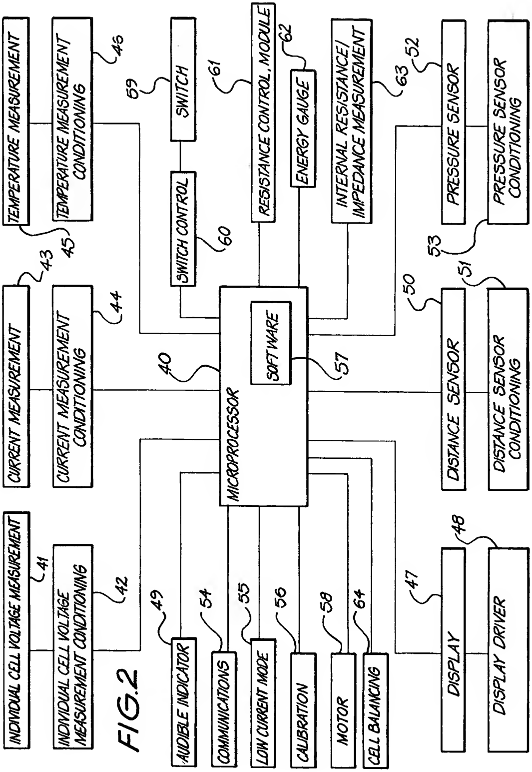

TEMPERATURE MEASUREMENT
TEMPERATURE MEASUREMENT CONDITIONING
SWITCH
SWITCH CONTROL
RESISTANCE CONTROL, MODULE
ENERGY GAUGE
INTERNAL RESISTANCE/ IMPEDANCE MEASUREMENT
PRESSURE SENSOR
PRESSURE SENSOR CONDITIONING
CURRENT MEASUREMENT
CURRENT MEASUREMENT CONDITIONING
MICROPROCESSOR
SOFT WARE
DISTANCE SENSOR
DISTANCE SENSOR CONDITIONING
INDIVIDUAL CELL VOLTAGE MEASUREMENT
INDIVIDUAL CELL VOLTAGE MEASUREMENT CONDITIONING
AUDIBLE INDICATOR
COMMUNICATIONS
LOW CURRENT MODE
CALIBRATION
MOTOR
CELL BALANCING
DISPLAY
DISPLAY DRIVER
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FIG.2

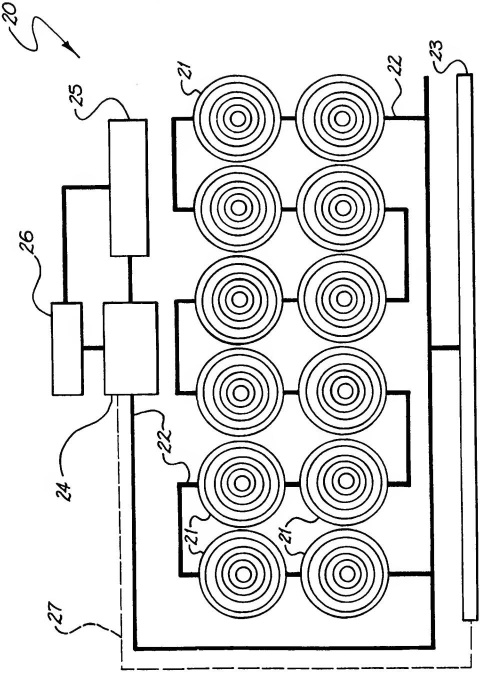

FIG. 3

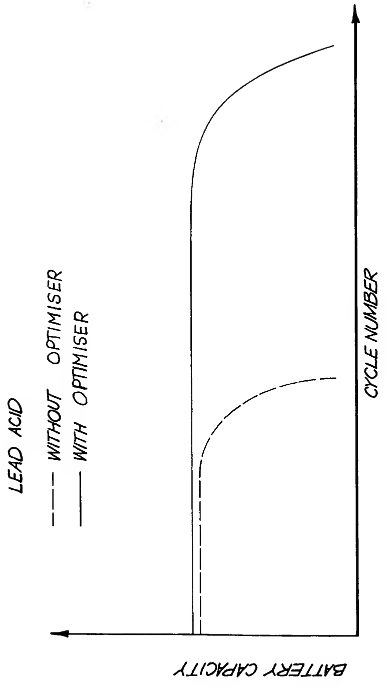
LEAD ACID
— — WITHOUT OPTIMISER
—— WITH OPTIMISER
CYCLE NUMBER
BATTERY CAPACITY

FIG. 4

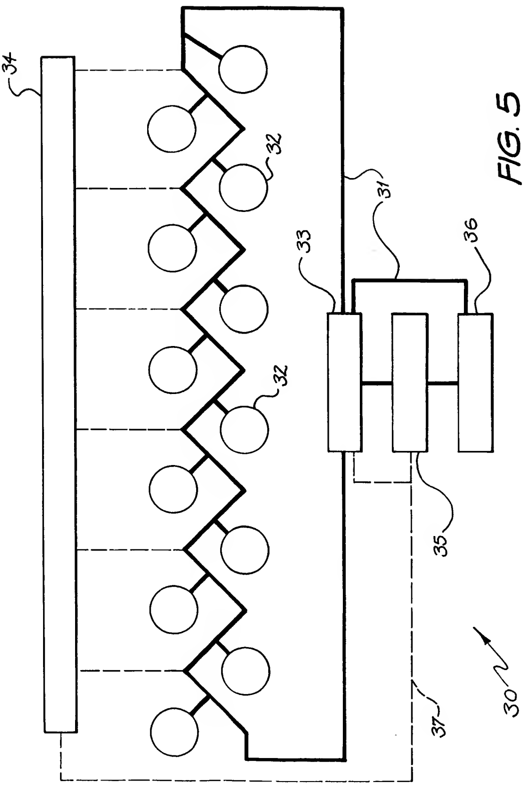

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No. **PCT/AU 99/00465**

A.	**CLASSIFICATION OF SUBJECT MATTER**
Int Cl[6]:	**H02J 7/00, G01R 31/38**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC H02J 7/00, H01M I/C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC AS ABOVE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT: Battery and Gauge and energy or power
JAPIO: as above

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0711 016 A2 (MITSUBISHI DENKI KABUSHIKI KAISHA) 08 May 1996 Page 5, line 6 to page 6, line 47	1 - 5
A	US 5,315,228 A (HESS ET AL) 24 May 1994 Column 2, line 26 to column 3, line 29	1 - 5
A	US 4,333,149 A (TAYLOR ET AL) 01 June 1982 Column 2, line 11 - 38	1 - 5

☐ Further documents are listed in the continuation of Box C

☒ See patent family annex

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 July 1999	-3 AUG 1999

Name and mailing address of the ISA/AU	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU 99/00465

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
EP	0711016	JP	8140270	US	5672951		
US	5,315,228	AU	34749/93	CA	2106672	DE	69322320
		EP	577810	WO	9315412		

END OF ANNEX